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The identity of the adventive *Gryllotalpa* Latreille species (Orthoptera: Gryllotalpidae) in Hawaii, with illustration of male genitalia of *G. orientalis* Burmeister

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Abstract. The adventive mole cricket species (Orthoptera: Gryllotalpidae) in Hawaii is apparently *Gryllotalpa krishnani* Arun Prasanna et al., 2012. The adventive was long thought to be *Gryllotalpa africana* Palisot de Beauvois, 1805. From 1983 until 2008 it seemed that *Gryllotalpa orientalis* Burmeister, 1839 might be the adventive's correct name. However, male genitalia and tegmental characters of Hawaiian specimens match features of *G. krishnani* and not *G. orientalis*.

Key words. Adventive mole cricket, invasive mole cricket, pest mole cricket, identification.

Introduction

An online version of the Hawaiian Arthropod Checklist Database of the Bernice P. Bishop Museum (Pyle 2002) listed *Gryllotalpa africana* Palisot de Beauvois as an adventive species on the islands of Kauai, Maui, and Oahu. Adventive species are those that arrived from elsewhere by some means and are not native; they include those that have arrived by entirely natural means, those that arrived as hitchhikers in cargoes, and those that were introduced deliberately. The online version has been withdrawn for updating, leaving an older, printed version (Nishida 1994).

"*Gryllotalpa africana*" was noted by Perkins (1899) as a new arrival on the island of Oahu and damaging to sugarcane. At least by 1923 it was also on the island of Kauai and damaging to newly planted sugarcane and the banks of irrigation ditches (Swezey 1923). Its presence as a harmful adventive species (i.e., an invasive species) prompted a biological control campaign (Williams 1928).

The identity of the mole cricket occurring in Hawaii became very questionable when Townsend (1983), decades later, published a revision of Afrotropical species of *Gryllotalpa* Latreille. He characterized *G. africana,* including the song and genitalia of the male which have characteristically long ventral processes. He stated that *G. africana* does not occur outside Africa, and "in Asia and Indonesia it is apparently replaced by *G. orientalis* [Burmeister], previously thought to be a synonym of [*G.*] *africana*." Graaf et al. (2005) published a report on *G. africana* in South Africa, re-recorded its song to confirm the earlier analysis by Townsend (1983), and noted that the characteristics of this song do not match the characteristics of the song of mole crickets in Hawaii as given by Nickle and Castner (1984). This confirmed the supposition above that mole crickets in Hawaii are not *G. africana*.

Townsend examined specimens of *G. orientalis* and designated a lectotype male, but he did not dissect and illustrate the genitalia. It seemed more likely that Hawaii's pest mole cricket would be an Asian species, and based on statements by Townsend (1983), it might or might not be *G. orientalis* (Frank and Parkman 1999; Frank and Leppla 2008; Frank et al. 2010). Not until late 2005 was the listing in Orthoptera Species File Online (Cigliano et al. 2019) changed to remove *G. orientalis* from synonymy with *G. africana*.

There is yet no revision of all species of *Gryllotalpa* occurring in eastern Asia, although several species have recently been described albeit without characterization of their songs and without modern redescription of *G. orientalis*. It is not my intention to revise the eastern Asian species. Evidently, characterization of *G. orientalis* was needed, and to accomplish this I (1) borrowed the lectotype of *G. orientalis* designated by Townsend (1983), and (2) borrowed 10 Hawaiian specimens of "*G. africana*" from the Bernice P. Bishop Museum (BPBM). My objective was to identify the (one, so far as I knew) *Gryllotalpa* species that occurs in Hawaii because I denied its earlier identification as *G. africana*.

Townsend (1983: 185) stated that "[G.] *minuta*" is common in the Oriental region but does not occur in Africa" despite the original description (by Burmeister 1839) bearing the words "Vom Kap", which writers assumed meant from the Cape of Good Hope. The type locality is therefore unclear and is at least as confusing as are Burmeister's statements of the locality for *G. orientalis* Burmeister (1839: 739).

Ingrisch (1990: 167, fig. 63) drew the genitalia of male *G. minuta*. However, the genitalia of Hawaiian mole cricket specimens seem not to have been compared.

Materials and Methods

Collection codens. Specimens were borrowed from three institutions for this study. The following acronyms denote depositories for specimens used here.

BPBM Bernice P. Bishop Museum, Honolulu, Hawaii, USA.
FSCA Florida State Collection of Arthropods, Gainesville, FL, USA.
MNHU Museum für Naturkunde der Humboldt-Universität zu Berlin, Berlin, Germany

Dissection. Practice in extraction of male genitalia of abundant *Neoscapteriscus* Cadena-Castañeda mole cricket specimens pointed to a method in which dried, preserved, mole cricket males may be placed in a sonic bath in water with a few drops of dishwashing detergent for ≈ 100 min. This softened the body sufficiently that a transverse cut could be made with spring-loaded micro-scissors in the intersegmental membrane caudal to abdominal segment 5, followed by lateral cuts to the apex of the abdomen. The exoskeleton was then peeled back to the apex of the abdomen and the abdominal contents were removed with fine forceps to a Syracuse dish with 20% KOH. After ≈ 17 hr of digestion in 20% KOH at room temperature, the sclerotized structure of the genitalia became apparent in the materials within the Syracuse dish. Further digestion in 20% KOH to remove extraneous connective tissue became risky because it might leave no more than a pile of the most indigestible sclerotized structures. Flensing, to use needles to tear connective tissue from the minute sclerotized structures, might have been at least as harmful to the specimens, so I did not attempt it. The major structures of the male genitalia may be discerned by this method, although it is not ideal. Note that the parameres of *Gryllotalpa* males are not articulated to the epiphallus but are held in position by connective tissue. Thus, when connective tissue is dissolved away, the parameres separate from the epiphallus.

Material examined. Specimens examined were from:

Philippines: The male lectotype of *G. orientalis* Burmeister is labeled: "Manila Meyer Tranqueb Hagen/ Co-Type/Inda N sub orientalis Burm/ 998/ Handb. Ent. **2**, 1839, p. 739/ *Gryllotalpa orientalis* Burmeister LECTOTYPE det B.C. Townsend, 1982/ Lectotype/ DORSA BG 00218S01". Color photographs of this lectotype and its labels are available online through Deutsche Orthopteren Sammlungen (DORSA) via Cigliano et al. (2019). Genitalia were dissected from the lectotype and appear as in Fig. 3, 4. Length 2.7 cm as measured in the online DORSA photograph. *Gryllotalpa orientalis "*Burmeister, 1838: 739" (lectotype - male, Philippines: Manila; in MNHU, Berlin); Townsend, 1983: 176, 185. The lectotype has flight wings longer than the abdomen. Burmeister's book was published in two volumes in 1838 and 1839. Librarians perhaps prefer to cite publication as in 1838, but biologists wishing to cite the date of description of *Gryllotalpa orientalis* and *G. minuta* should cite 1839.

Compare *G. orientalis* with the *Gryllotalpa minuta* male specimen collected in Nepal (DORSA specimen online). DORSA is a project of the Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn. The *G. orientalis* lectotype is in the Museum für Naturkunde, Berlin, but the *G. minuta* specimen photographed is in the Zoologische Staatssammlung München. It is unfortunate that the lectotype of *G. orientalis* apparently was originally pinned through the harp of the left tegmen, that original error perhaps being noticed later and a pin placed instead through the thorax; thus, the exact shape of the harp and adjoining cells is difficult to interpret.

Hawaii: Ten specimens in the Bernice P. Bishop Museum were examined, all from the island of Oahu. Three are males: "Honolulu 1-1-19/ J.A. Kusche Collector", "Wahiawa 10.31.20/ O.H. Swezey Collector" and "HAWAIIAN IS., Oahu, Kaneohe 1995, J. Jacoba, Coll., BISHOP MUSEUM". The remaining seven specimens borrowed are females appearing very similar to the males except for tegmen (forewing)

venation. Genitalia of both short-winged males were removed by dissection and cleared in KOH and are identical to each other. "Hawaiian Is., Oahu, Coll. O. H. S."; "Manoa Ex, N. Kaunkami"; "HAWAIIAN IS., Oahu Is, Makiki, Nehoa St. 7.xii,1989. K. Stockton, Coll Bishop Museum"; "Oahu, 950 ft., Puunui, S.W.K."; "*Gryllotalpa africana* Beauvois det. H.F. Strohecker. Oahu, Nov 11. 1917 Hy. H. Severin Coll."; "Honolulu, T.H., 1-18-45"; "Honolulu, XI-2-27, Central Y.M.C.A, Cafeteria floor, W. H. Meineke Collector". One female in the Florida State Collection of Arthropods is labelled: "H[AWAII]. KAUAI, tennis court, 28-XI-77, B. Shigemoto".

Results and Discussion

The male genitalia of mole crickets provide excellent taxonomic characters but take considerable effort to dissect and illustrate well because of their complexity. I have followed the nomenclature of Townsend (1982) and Ingrisch (1990) but have added the expression flange to the forward-protruding structure from each half of the transversal sclerite.

Gryllotalpa africana Palisot de Beauvois, 1805, is confined to Africa, and *Gryllotalpa fossor* Scudder, 1869, is one of its synonyms (Townsend 1983) so likewise is confined to Africa. A description including illustrations of the male genitalia is given by Townsend (1983), showing that the ventral processes are extraordinarily long (Fig. 7), and see Fig. 10 for names of the parts of *Gryllotalpa* genitalia. There is no evidence that this species occurs in Hawaii. Thus, the literature on invasion of the Hawaiian Islands by "*G. africana*" including its attempted biological control by *Larra polita* (Smith) (Hymenoptera: Crabronidae) imported from the Philippines is incorrect in the identity of the mole cricket.

Gryllotalpa orientalis Burmeister (1839: 739) is "Aus Ostindien von Tranquebar; auch aus Java (*Gr. minor* Hagenb.) und vom Vorgebirge der Guten Hoffnung" [from Tranquebar in eastern India and also from Java (*G. minor* Hagenbach), and also from the foothills of the Cape of Good Hope]. The lectotype bears a label indicating both Manila (Philippines) and Tranquebar (at that time a Danish possession in southeastern India, now called Tharangambadi and in the state of Tamil Nadu). Townsend (1983: 176) explained that the lectotype male was deposited in the Tranquebar Museum, but was collected in Manila, Philippines. The transversal sclerites of the male genitalia have no flange and are simply rounded (Fig. 3, 4). The flight wings of this lectotype are longer than the abdomen.

Gryllotalpa minuta Burmeister (1839: 740) has a published type locality of "Vom Kap", which readers have reasonably interpreted as indicating "from the Cape of Good Hope", but Townsend (1983: 185) states that *G. minuta* "does not occur in Africa." It is likely he inferred this as a corollary of his intensive Africa-wide (and beyond) study of thousands of *Gryllotalpa* specimens. It may very well be the species whose genitalia are illustrated by Chopard (1969: 4, fig. 6) under the name '*G. fossor* Scudder' (wrongly identified). Chopard (1969) reported '*G. fossor*' from India, Bhutan, Nepal, Pakistan, Burma, Malaysia, and Singapore, and as a pest in India. Ingrisch (1990) stated that *G. minuta* is common in the oriental region. Genitalia are illustrated by Ingrisch (1990: 167, fig. 63, also here Fig. 8). *Gryllotalpa minuta* has the flight wings shorter than the abdomen (Ingrisch 1990 and online DORSA photograph).

Gryllotalpa krishnani Arun Prasanna et al. (2012). The original description (with type locality Tiruchirappalli, Tamil Nadu, India) and illustrations match the invasive mole cricket species in Hawaii. Genitalia are broadly similar to those of *G. minuta* but the median prolongation of the epiphallus extends well anterior to the anterior flanges of the transversal sclerite (Fig. 5, 6) which is not so in the lectotype of *G. orientalis* (Fig. 3, 4). The transversal sclerites have forward-pointing flanges (as in *G. minuta*) which makes the two transversal sclerites with their flanges appear like a letter M; in this, it resembles *G. minuta* but not *G. orientalis*. Compare the photograph of the harp in a Tamil Nadu *Gryllotalpa krishnani* by Arun Prasanna et al. (2012: 42, fig. 1C), and a Nepalese *Gryllotalpa minuta* by Ingrisch (1990: 67, fig. 53). The harp is a harp-shaped cell on the tegmen forming part of the stridulatory apparatus of males; the surrounding cells also are of diagnostic value. Flight wings are slightly longer than the abdomen according to Arun Prasanna et al. (2012: 42) but not so in the obscure habitus photo they provide (their fig. 1A). Perhaps the presence of short-winged adults among the long-winged adults (Fig. 1, 2) confused them; this condition so far seems not common among *Gryllotalpa* spp. The examined specimens included three short-winged adults (one female and two males) and eight long-winged adults. The tegmen venation of short-winged males is the same as that of long-winged males; likewise, the tegmen venation of

the short-winged female is the same as that of the long-winged females.

Such is the state of Asian mole cricket taxonomy that I found only one paper (Tan 2016) mentioning *G. krishnani* since its original description. No writer has yet mentioned finding this species elsewhere. The reason it has not been declared present in other localities might be due to its restricted presence and recent description, but just as likely because few authors have the patience to dissect mole crickets in order to identify them.

The genitalic illustrations by Tan (2016) of 16 species occurring in eastern Asia allow easy interspecific comparison. Even if they are somewhat stylized, they can point the way to another illustration in another paper that may help.

An added complication is that Townsend (1983) stated he could not distinguish specimens of *G. orientalis* from those of an African species, *G. debilis* Gerstaecker, 1869, although he chose not to synonymize the latter name. Townsend (1983) reported *G. debilis* as the only African species of which macropterous and micropterous forms are known; Endo (2006) reported such forms in *G. orientalis* in Japan (short-winged forms from September to June, and long-winged forms the rest of the year). Here I point out again that three of the Hawaiian mole crickets I examined are short-winged; they are the male collected in Wahiawa, a male collected in Honolulu, and the female collected in Puunui. However, other than their short wings, I saw no difference between them and the others; tegmen (forewing) venation seems identical. Because adult female mole crickets are by far the main dispersers, it makes ecological sense for the males to have short wings and be flightless. The male genitalia of the lectotype are illustrated in Fig. 7–8. This concept needs further research. Could it be that *G. debilis* Gerstaecker is the species reported by Endo (2006) as *G. orientalis*?

For those interested in the damage caused by this mole cricket in Hawaii, I have found no reports for many decades. However, such lack of reports suggests success of the biological control program of the late 1920s followed by lack of interest. The same happened during the biological control program against *Scapteriscus* Scudder mole crickets (now *Neoscapteriscus* Cadena-Castañeda) in Florida (Frank and Walker 2006).

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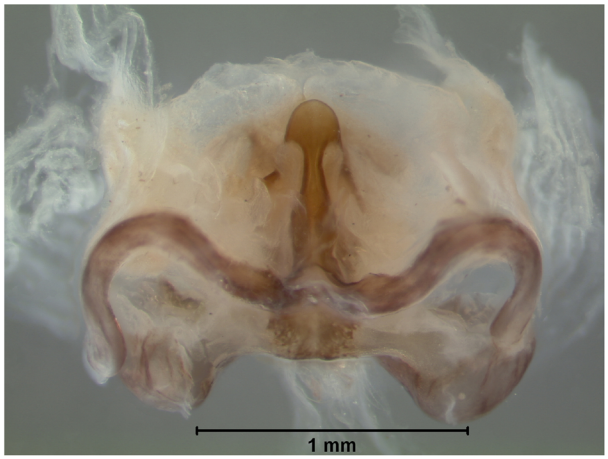
Figures 1–2. *Gryllotalpa krishnani* habitus from above. **1)** Hawaiian short-winged male, photograph by Lyle Buss. **2)** Hawaiian long-winged male, photograph by Lyle Buss.



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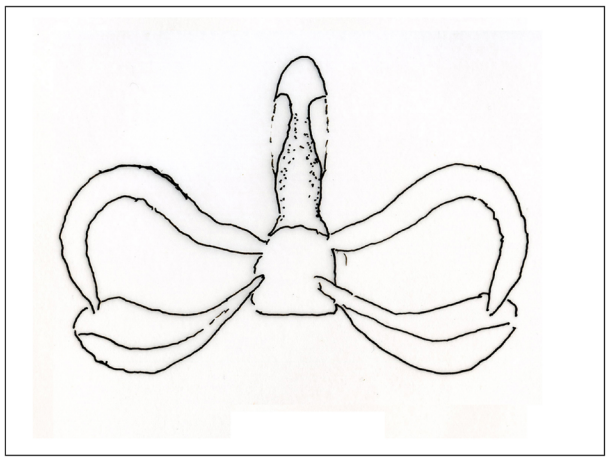

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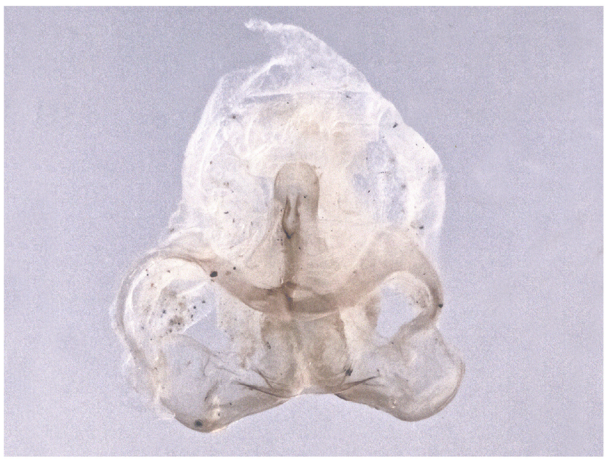

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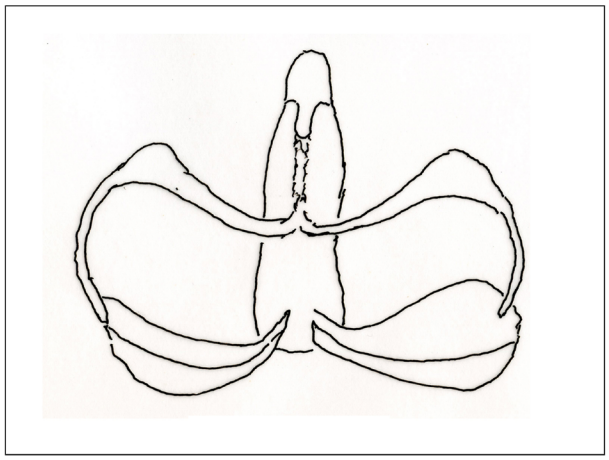

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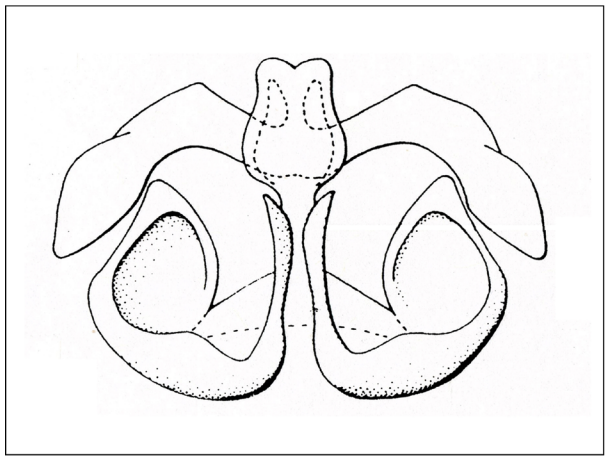

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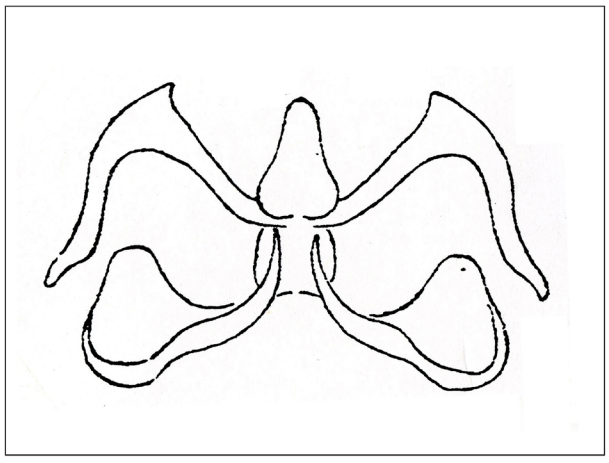

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Figures 3–8. Male *Gryllotalpa* genitalia in ventral view: **3)** *Gryllotalpa orientalis* lectotype, original photograph by Lyle Buss. **4)** *Gryllotalpa orientalis*, tracing from photograph. **5)** *Gryllotalpa krishnani*, original photograph by Walter Keller. **6)** *Gryllotalpa krishnani*, tracing from photograph. **7)** *Gryllotalpa africana* after Townsend (1983). **8)** *Gryllotalpa minuta* after Ingrisch (1990).

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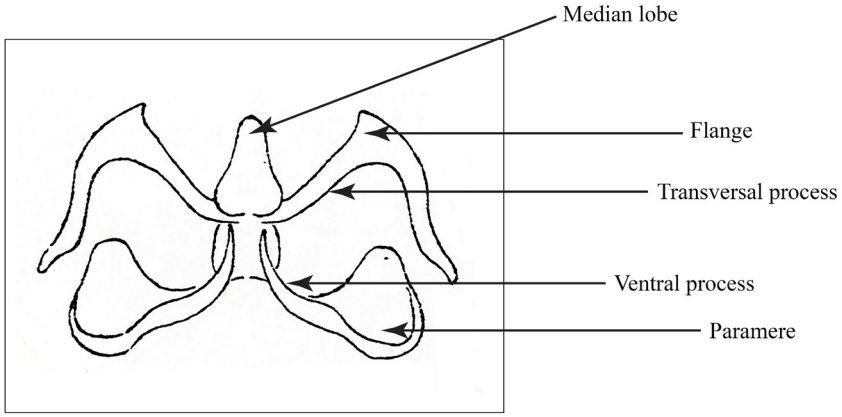

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Figures 9–10. *Gryllotalpa* morphology. **9)** Left tegmen (forewing) of male *Gryllotalpa krishnani*, showing harp, photograph by Lyle Buss.**10)** Named parts of male *Gryllotalpa* genitalia.